Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
LightSquared Subsidiary, LLC	)	**IB Docket No. 11-109,**
	)	**SAT-MOD 20101118-00239**
Application for Modification of Its Authority for an Ancillary Terrestrial Component	)	

GPS Interference Report of Clearwire Corporation

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LightSquared "Live Sky" Test Results

Las Vegas – May 16 through May 27, 2011

This report provides a synopsis of impacts to the Clearwire commercial system in Las Vegas measured during LightSquared's "Live Sky" BTS testing that took place from May 16 to May 27, 2011.

A. EXECUTIVE SUMMARY

1. LightSquared's "Live Sky" test of GPS interference in Las Vegas caused a Clearwire base station co-located with a LightSquared base station to lose GPS link; the site shut itself down automatically to prevent interference to the rest of the market.

2. The test plan was designed to answer whether significant GPS interference will result from LightSquared's operation—which was demonstrated conclusively. Clearwire would have to replace GPS antenna across its nationwide network, which would potentially entail 15,000-20,000 new GPS antennae, and the considerable logistics and cost this would involve.

3. LightSquared position on payment for mitigation of GPS interference they will cause is at odds with the plain language of the MSS ATC regulation at 47 CFR §25.255; this regulation requires the MSS ATC entrant "must resolve any such interference. If the MSS ATC operator claims to have resolved the interference and other operators claim that interference has not been resolved, then the parties to the dispute may petition the Commission for a resolution of their claims." Thus far, LightSquared has said it is unwilling to pay for mitigation of harm to commercial terrestrial networks.

4. The test was not sufficient to ascertain what mitigation measures would be adequate to reduce or eliminate harm to GPS caused by LightSquared's operations. The tests failed to accurately depict a real world environment because the tests were underpowered, intermittent, and with inadequate site density. To determine the true degree of GPS interference or whether mitigation measures will be adequate, it will be necessary to have an interference test which reflects real-world deployment conditions before it can be determined whether co-existence with GPS is possible in the upper or lower band of LightSquared's spectrum.

5. The recently proposed power "reduction" by LightSquared may be *at or above* the levels where interference was demonstrated in Las Vegas.

6. Even with LightSquared's proposed power reduction and its decision to initially deploy using lower band spectrum, additional testing is necessary because preliminary tests show a strong probability of interference from the lower band for several classes of devices, especially if the power reduction is accompanied by greater cell density.

B. Background

Clearwire is a provider of commercial 4G mobile broadband services to over 70 U.S. markets covering 130 million people. The Clearwire 4G network utilizes mobile WiMAX technology to provide these services. Clearwire has deployed more than 15,000 WiMAX base stations across its markets in a variety of physical sizes and configurations ranging from conventional ground based and tower mounted radio systems to small size picocells. As a key part of base station operations, Clearwire uses commercial GPS technology to provide a stable timing reference for Time Division Duplex ("TDD") based transmissions. Clearwire also uses various portable and handheld GPS based devices to deploy, optimize and maintain its network.

C. LightSquared Test Plan

The FCC has conditioned LightSquared's waiver to operate both satellite and terrestrial based mobile services on the successful resolution of a GPS interference study due to widespread concerns regarding the impairment of existing GPS services from LightSquared's operations. As part of this study, LightSquared created a limited test bed in Las Vegas and Boulder City, Nevada, to measure interference to carrier networks relying on GPS and to certain GPS-based devices. Clearwire has commercial operations in Las Vegas and attempted to measure the impact of LightSquared's operations on its radio network during the testing period.

LightSquared chose three sites in Las Vegas and one site in Boulder City for testing. Attached as Table 1 are the configuration parameters for the LightSquared test sites and Figures 1-3 are Google Maps showing the test site locations. As shown in these maps, LightSquared's sites were configured with either two or three sectors. The two sector sites are near airports and the omitted sector would have been aimed directly at an airport. These sectors were presumably omitted because of the potential impact to aeronautical services, and more stringent power flux density limits that LightSquared must abide by near airports, "aircraft stands", and "navigable waterways."[1]

Attached as Figure 4 is a map showing the location of the LightSquared test sites in Las Vegas and the commercial Clearwire sites in the immediate area. Clearwire site LSV0095 is co-located with LightSquared site LVGS0068.

LightSquared configured the base stations to operate using up to two channels of FDD LTE service as shown in Table 2. A low band channel operated at 1526.3-1531.3 MHz on the downlink and an upper band channel operated at 1550.2-1555.2 MHz on the downlink. The purpose of the single channel testing was to isolate individual channels and determine GPS susceptibility within specific frequency ranges. The dual frequency tests were intended to test/illustrate the evolution of potential intermodulation (signal mixing) products in victim receivers.

The testing was conducted from May 16 to May 27 and consisted of operating the LightSquared transmitters in various channel configurations as shown in Table 2. Transmissions were cycled on and

[1] *See* 47 CFR §25.253(5-7).

off in 15 minute intervals starting at midnight and lasting until 6:00AM. The base stations were left on continuously for the last hour of testing on May 27.

Apparently due to a software limitation, MIMO testing with two carriers was not possible. This caused a net reduction in output power to 59 dBm EIRP for the two carrier tests. The antenna used was a two port crossed polarization unit, with one element at +45° and one at -45°. In normal MIMO operation, both elements would be active on the same channel. During dual channel testing, however, LightSquared used only a single antenna port for each separate channel transmitter. NOTE: <u>In a commercial deployment, transmitters would be capable of supporting two channel operation with MIMO gain on each channel. This would result in 3 dB more power per carrier than was tested.</u>

Tests on May 16th and 17th were radiating with ~ 59 dBm EIRP for single channel operation and ~ 56 dBm EIRP (per channel for dual channel operation.)

LightSquared Site ID	Latitude	Longitude	Antenna Height AGL (ft)	Number of Sectors	Azimuths (degrees)	City
LVGS0053-C1	35.9697	-114.8681	60	2	30, 270	Rural
LVGS0068-C1	36.1245	-115.2244	55	3	0, 120 ,240	Suburban
LVGS0160-C1	36.127	-115.189	50	3	0, 120, 240	Urban
LVGS0217-C1	36.1065	-115.1705	235	2	0, 240	Dense Urban

Table 1

LightSquared Base Station locations, antenna heights, number of sectors, orientation, and estimated morphology type.

Antenna characteristics:

- 65° horizontal aperture
- 7.5° vertical beamwidth
- 2° electrical downtilt from indicated height

Antenna patterns and close in illumination estimates are provided in the Appendix. At these heights and with this downtilt value, the 3 dB vertical beamwidth from all sites extends to the horizon.

Test Day	Date	Frequency Bands to be tested		Sites to be tested			
		1526.3-1531.3 MHz LOWER BAND	1550.2-1555.2 MHz UPPER BAND	Site #68	Site #160	Site #217	Site #53
1	5/16/2011		x	x		x	
2	5/17/2011	x		x		x	
3	5/18/2011	x	x	x		x	
4	5/19/2011		x		x		x
5	5/20/2011	x	x		x		x
6	5/21/2011	x		x		x	
7	5/22/2011		x	x	x	x	
8	5/23/2011	x		x	x	x	
9	5/24/2011	x	x		x		x
10	5/25/2011	x			x		x
11	5/26/2011	x	x	x	x	x	
12	5/27/2011	x	x				x
12	5/27/2011	x		x		x	

Table 2

As shown above, the LightSquared test plan varied the combinations and locations of the frequencies under test every night.

Figure 1 - Las Vegas Market – LightSquared Test Locations

This slide graphically depicts the 4 LightSquared test locations, and illustrates their sector orientations.

CLEAR

Figure 2 - Las Vegas Locations

Note sector orientation does not illuminate McCarran Airport.

CLEAR

Figure 3 - Boulder City Location

Note sector orientation does not illuminate Boulder City Municipal Airport.

Figure 4 - Las Vegas Detail, LightSquared & CLWR Sites

Location detail of CLWR stations with proximity to LightSquared transmit sites. Our GPS receive antenna is omni-directional. Note shared site #95 at the upper left.

D. GPS Interference/Impact to Clearwire

On the morning of May 16, coincident with the activation of LightSquared's Upper Band channel (1550.2-1555.2 MHz) at LightSquared site #68, the GPS reference receiver at the co-located Clearwire site LSV0095 lost satellite lock. After three minutes without a satellite reference signal, the Clearwire Base Station automatically shut down its transmitter to prevent unsynchronized operation with the rest of the network.

The GPS interference from LightSquared caused the Clearwire site to go out of service within one to three minutes of the beginning of the test. LightSquared was performing intermittent tests, 15 minutes on, 15 minutes off. During the periods where there was no test signal, GPS coverage resumed for a few minutes, and was again knocked out immediately when testing resumed.

Due to the site outage, Clearwire's Network Operations Center was notified, and Las Vegas field maintenance forces contacted LightSquared. LightSquared offered to temporarily supply Clearwire with a PCTel filtered GPS antenna to use at the site, and this antenna was substituted for the existing model. While the filter mitigated the interference in this limited test bed, according to manufacturer specifications, the filtered antenna has a 3 dB increase in its nominal noise figure,[2] equivalent to a 50% drop in receive power which represents a significant impairment to the receiver's functionality.

Clearwire site #95 consists of a cell tower with an adjacent ground-mounted base band cabinet and an integrated GPS receiver with an external antenna at ~ 6 feet. Because of the low site density, and the vertical separation of 49 feet between the LightSquared antenna and the Clearwire GPS antenna, an additional intermediate filter was not necessary. We anticipate that in many rooftop co-location scenarios (without vertical separation), such an intermediate filter will be required.

E. Deficiencies of GPS interference testing

While the test clearly demonstrated GPS interference from LightSquared's operations, because the test was underpowered, intermittent, and had inadequate cell site density, it did not provide a real-world assessment of interference issues that may arise in an actual deployment, or the mitigation measures that would be required to properly remedy the harm to GPS.[3]

1. **The test was significantly underpowered** compared to LightSquared's planned operational levels (even with their 50% power "reduction"), and was conducted far below LightSquared's authorized power limits. It is Clearwire's understanding that LightSquared is authorized to operate with 10 dB more power than what was tested in Las Vegas and Boulder City. By

[2] See Appendix, "PCTel Filtered GPS Antenna".

[3] Clearwire ordinarily would have submitted these critiques and recommendations to the FCC's GPS interference Technical Working Group (TWG), but our request for admission to the TWG has not been granted as LightSquared has not approved our observer status (although the other TWG co-chair has supported our participation). Clearwire attempted to join the TWG on June 8, 2011 once we fully appreciated the severity of GPS interference that would occur based on Las Vegas test results.

operating the LightSquared channels at reduced power output, the amount of interference that Clearwire detected was artificially decreased. Increasing power to real world levels will cause significantly more GPS interference to be recorded. Every 6 dB increase in power output effectively doubles the interference range. Even with LightSquared's proposed power "reduction" in their modified plan[4]—not reduced from the power level where interference was documented, but "reduced" from their maximum authorized power—they will still be operating at a power level *at or above* the power level where interference was documented in Las Vegas testing. This ostensible "reduction" seems disingenuous given that LightSquared executives, when challenged in May that they were not testing their equipment at their authorized power limit, said that they had no intent to operate at that power level.[5] Moreover, LightSquared initially stated that during Las Vegas testing they would use equipment identical to that which they would deploy commercially. FCC Technical Working Group (TWG) members discovered this was not the case, that LightSquared would test at 50% of the power they initially claimed, and LightSquared resubmitted the May progress report[6] with a revised Appendix[7] noting the power change.

2. **The test was intermittent**. By cycling on and off power every 15 minutes, LightSquared avoided the full extent of problems that would be experienced in an actual deployment, especially in devices/networks that have "GPS holdover" features. Some systems, such as Public Safety trunked radio systems that rely on GPS timing for proper operation, have a holdover feature that allows them to continue operating in the event of brief GPS interruptions. The length of this holdover time varies, but it is never less than approximately 30 minutes. If the GPS signal is received anytime during the "holdover" period, the GPS signal recalibrates the holdover timer, and resets the local timing signal. By allowing devices to have a 15 minute "quiet period", this gives the system a chance to reset its holdover timer. However, this "quiet period" would not exist in an actual deployment where the network would transmit a constant signal that would interfere with GPS. The Clearwire station at site #95 was not equipped for extended holdover, so it lost synchronization within 3 minutes of losing the satellite signal.

[4] "Recommendation of LightSquared Subsidiary, LLC". *In the Matter of LightSquared LLC, Application for Modification of Ancillary Terrestrial Component, SAT-MOD 20101118-00239.* Ex parte presentation, June 30, 2011.

[5] *See e.g.* Charlotte Adams, *"The GPS Crisis: how serious is it?"* Avionics Intelligence (May 4, 2011). "Although LightSquared has given the U.S. GPS Industry Council (USGIC), the co-chair of the TWG, verbal assurance that the company will not exceed 1.5 kilowatts (32 dBW) in the 1545-1555-MHz band, LightSquared is authorized to transmit at as much as 15.5 kilowatts (42 dBW) in its allotted frequency bands."

[6] "TWG Progress Report #3, May 16, 2011". *In the Matter of LightSquared LLC, Application for Modification of Ancillary Terrestrial Component, SAT-MOD 20101118-00239. See* p. 4: "LightSquared is using base stations identical to the ones which it will use for its network deployment; however due to unique circumstances of the test setup, in single frequency mode, the test sites will operate at power levels of approximately 59 dBm EIRP per channel as opposed to the 62 dBm EIRP per channel currently planned for LightSquared's initial commercial deployment. For two carrier tests, the MIMO gain will not be present, reducing the EIRP a further 3 dB per channel to approximately 56 dBm EIRP (see Note 1 in Appendix G)."

[7] "Revised Appendix G". *In the Matter of LightSquared LLC, Application for Modification of Ancillary Terrestrial Component, SAT-MOD 20101118-00239.* Ex parte presentation by LightSquared, May 23, 2011.

3. **The test had inadequate site density**. Even though interference was experienced at a Clearwire base station during LightSquared's limited test, it is impossible for Clearwire to successfully extrapolate from the limited data set the full extent of interference that would be experienced in an actual deployment. The low number of LightSquared sites used for the test and site spacing and overlap zones between the sites did not provide the density of concatenated signal strength to be expected in a commercial deployment. Signal powers sum in overlap areas, and this summing likely will cause impairment zones to expand significantly once testing is conducted in a real-world manner.

4. **The test design did not use a standard 3 sector base station configuration in all cases**. For example, LightSquared avoided illumination of airports with this test deployment, presumably to avoid disruption of aviation GPS. Given that no sites were tested with sectors pointed towards airfields, it is difficult to gauge how far the GPS interference stand-off zone will need to be in order to avoid aviation interference. Given that in a real deployment LightSquared will surely want to cover customers living or working near airports, this raises substantial concerns that the testing was inadequate to determine whether the company can abide by stringent interference limits while at the same time providing ubiquitous coverage.

5. **A two-channel MIMO transmitter was never used, as would be used in a real deployment.** The original testing plan called for two equal power, two-channel MIMO transmissions. However, for Las Vegas, LightSquared indicated they did not have a two channel MIMO transmitter available. So, rather than do filter combining, LightSquared decided that it would be acceptable to simulate the transmission by attaching one transmitter from one channel to one antenna element, and one transmitter from the other channel to the other antenna element. But this creates two, uni-polar transmissions that are orthogonal to one another (for example, frequency F1 is transmitted at -45 degrees while F2 is transmitted at +45 degrees). This will result in much less opportunity for equal power mixing to occur during testing, which calls into question the overall results of the testing for intermodulation product evaluation. The uni-polar nature of the dual channel tests also reduced the incident power at any given target, and provided additional opportunities for a target to be located at a polar null point. If it was not possible to provide dual channel capable base stations, LightSquared should have used appropriate combining techniques to simulate an actual dual-channel MIMO deployment from a single crossed-pole antenna. Since testing did not demonstrate full power dual channel MIMO operation, it is not possible for Clearwire to fully characterize the performance impact of higher power without actually using higher power. Many non-linearity events are possible when specific power levels are exceeded.

6. **The test did not use realistic antenna downtilt for a LTE system; the 2 degree downtilt LightSquared used for testing means that the most severe interference zones (in the main lobe, closer to the tower) are understated.** Standard LTE deployments vary downtilt according

to morphology,[8] but will likely use antenna downtilt of 10-12 degrees for dense urban, 6-8 degrees for suburban, and 6 degrees for the most rural scenarios. By using an unrealistic downtilt value of 2 degrees, LightSquared is pointing the main lobe (where the worst interference will be experienced) much further away from the base of the tower, where the signal is attenuated by distance.[9] Because LightSquared's actual deployment is likely to use downtilt values that put the main lobe closer to the tower base, more severe interference can be expected.

7. **No definitive tests on rooftop co-location scenarios were conducted.** Clearwire studied potential rooftop co-locations and determined that in specific cases of direct illumination by LightSquared's transmitter, a supplemental filter will be needed in addition to the filtered antenna already required for co-located equipment. For typical Clearwire base station configurations where the antennas are mounted on a tower, the GPS antenna is mounted on or near a cabinet located at the base of the tower. In a commercial deployment by LightSquared, the probability of line-of-site conditions and co-location goes up dramatically and thus also the potential for interference.

F. Conclusions and Recommendations

1. The upper band carrier used by LightSquared will cause catastrophic interference and loss of lock to Clearwire base station GPS units either co-located or in close proximity with line-of-site conditions. A typical commercial deployment makes these conditions highly probable for both Clearwire and every other wireless network that relies on base station GPS connectivity.

2. The interference may be reduced at a subset of Clearwire base station sites by replacing the existing Clearwire base station GPS antennas with internally filtered units (though as noted below it is not possible to apply filters to all sites). The application of a filtered unit will cause a loss in sensitivity of the GPS system due to the electrical characteristics of the filtered antennas which may result in performance degradation at some sites. The cost of replacing the GPS units (material and labor) is significant given the large number of Clearwire base station sites, and given the large geographic range of GPS impairment from LightSquared's operations. It is difficult to accept the notion that Clearwire should incur huge cash and opportunity costs to downgrade GPS equipment with antennae that are less sensitive than the equipment used in networks today. Network operators are accustomed to bearing costs for enhanced

[8] *See* "3GPP Self-evaluation Methodology and Results: 'Assumptions'" at p. 11. Tetushi Abe (NTT DOCOMO, 3GPP TSG-RAN1 Vice Chairman). 3GPP LTE-Advanced Evaluation Workshop, Dec. 17-18, 2009. Available at http://www.3gpp.org/ftp/workshop/2009-12-17_ITU-R_IMT-Adv_eval/docs/pdf/REV-090007%20SelfEvalulation%20assumption.pdf

[9] See Appendix for an illustration of downtilt, and distances for inner radius of main lobe associated with 2 degree downtilt.

functionality, but it is odd to ask operators to pay for engineering, installation and equipment that works less well than equipment already installed in the network.

3. In locations where GPS interference mitigation may be possible, Clearwire is extremely concerned about the cost of mitigation. While LightSquared has been quick to note that they are following the FCC rules, their position on payment is diametrically opposed to FCC regulations. 47 CFR §25.255[10] clearly states that it the duty of the MSS ATC operator to resolve interference, and further, the rule outlines an official FCC complaint process if the MSS operator has not satisfactorily resolved that interference. In conversations between Clearwire and LightSquared executives, LightSquared has taken the position that they are not responsible for the cost of mitigation on Clearwire's network. This is counter to the plain language of the rule, which places the burden of mitigating GPS interference on the MSS ATC operator. Since FCC rules prudently and properly placed the burden of any potential interference on the party causing the disruption, the duty to pay for mitigation is no less a part of LightSquared's regulatory requirements than its out of band emission limits.

4. Because the GPS interference LightSquared will cause is so widespread, nearly all current and future Clearwire cell sites—15,000 to 20,000 cell sites—will require new GPS antennae. The cost of purchasing the antennae alone is quite substantial, and when coupled with the cost of engineering time for site visits, tower climbers, network testing after installment, etc., those costs quickly spiral out of control. Moreover, Clearwire's network is only one network of many that will experience GPS disruption, and is the "easiest" kind of interference to fix because it uses a narrowband GPS signal (unlike precision, aviation, and military GPS users), is stationary (unlike mobile users) and its base stations are large enough to accommodate filters (except e.g. picocells, which as noted below cannot be fixed). Yet the disruption to Clearwire's engineering and operations team alone would be immense, and would hinder our ability to continue deploying a network while we resolve a nationwide GPS interference problem. This same widespread GPS interference will be seen on all networks and all GPS devices near LightSquared's operations. If the FCC permits LightSquared to deploy their network and requires all other parties to bear the brunt of nationwide GPS interference, the costs will be almost incalculable.

5. Mitigating GPS interference is not possible in many locations. There are several alternative base station configurations (picocells and stealth enclosures for example) where it may be physically impossible to substitute a filtered GPS antenna for the low profile GPS antennas currently in use. As 4G deployments continue, and these alternative configurations become more numerous to meet growing demand for wireless broadband, this interference issue will compound. The

[10] §25.255 **Procedures for resolving harmful interference related to operation of ancillary terrestrial components operating in the 1.5/1.6 GHz, 1.6/2.4 GHz and 2 GHz bands.**

If harmful interference is caused to other services by ancillary MSS ATC operations, either from ATC base stations or mobile terminals, the MSS ATC operator must resolve any such interference. If the MSS ATC operator claims to have resolved the interference and other operators claim that interference has not been resolved, then the parties to the dispute may petition the commission for a resolution of their claims.

stealth enclosures are designed to meet rigid aesthetic and operational requirements placed upon Clearwire by municipalities and cannot accommodate the addition of filters.

6. Since a filtered GPS unit remained in place on the co-located site for the remainder of the testing, Clearwire did not evaluate interference from the lower band carrier and dual carrier operation. However, it is easy to conclude the dual carrier operation would have similar or worse effects and the probability of interference from the lower band carrier exists, particularly at co-located rooftops where separation distances are short and illumination is direct.

7. LightSquared's avoidance of airports with this test deployment either calls into question their ability to provide a ubiquitous network solution, or raises concerns about their ability to protect aviation users. LightSquared's ATC authorization was conditioned on more stringent Power Flux Density (PFD) limits near "navigable waterways" and "aircraft stands." To meet those limits, Clearwire calculates that they will either need considerable "stand-off zones" to protect sensitive users, or they will need an entirely different network configuration predicated on the existence of lower powered equipment which has not been tested for interference.

    i. Clearwire calculates that in order to meet the more stringent PFD limits near navigable waterways or aircraft standing areas, any base station sector pointed towards one of these areas would need to be set back approximately 5 km from the waterway or airport. It is not clear how LightSquared can turn up a ubiquitous coverage solution given that A) cities like New York City, Boston, Baltimore, Chicago, etc. are all at the edge of "navigable waterways", and B) "aircraft stand areas" includes, e.g. hospital helipads and helipads throughout urban areas. This would require broad swaths of urban areas to go uncovered.

    ii. In the alternative, if LightSquared believes it has lower-powered equipment that will work for coverage in these areas without a 5 km GPS interference stand-off zone (such as pico cells, etc.), such an alternative plan would necessarily entail greater network density and a whole range of equipment yet to be tested for its impacts to GPS performance.

8. If in fact it is determined that mitigation may be possible and further testing is warranted to determine more precise denial of service radii for the full range of equipment likely to be encountered in real deployments, further tests should be conducted as follows:

    i. Test must be conducted at either LightSquared's full authorized power, or at a level they will commit to not operate above on a going-forward basis. As we understand it, their commitment to operate at 50% of full authorization still allows them to transmit at power levels ABOVE where interference was demonstrated in Las Vegas.
    ii. Test must be conducted without intermittent gaps in signal which will show decreased effects for devices with GPS timing "holdover". 15 minute on/off testing is only sufficient for initial determination of whether interference is present. This unrealistic

test condition does not allow for proper evaluation of mitigation solutions, which can be determined only with a constant GPS disruption.

iii. Normal commercial site density must be used in order to gauge impacts from signal overlap.

iv. Standard 3 sector tower designs should be used in most or all cases.

v. Electrical downtilt values used in testing should reflect real-world values, as opposed to the unrealistic 2 degree downtilt LightSquared chose, which understates the most severe interference closer to the tower.

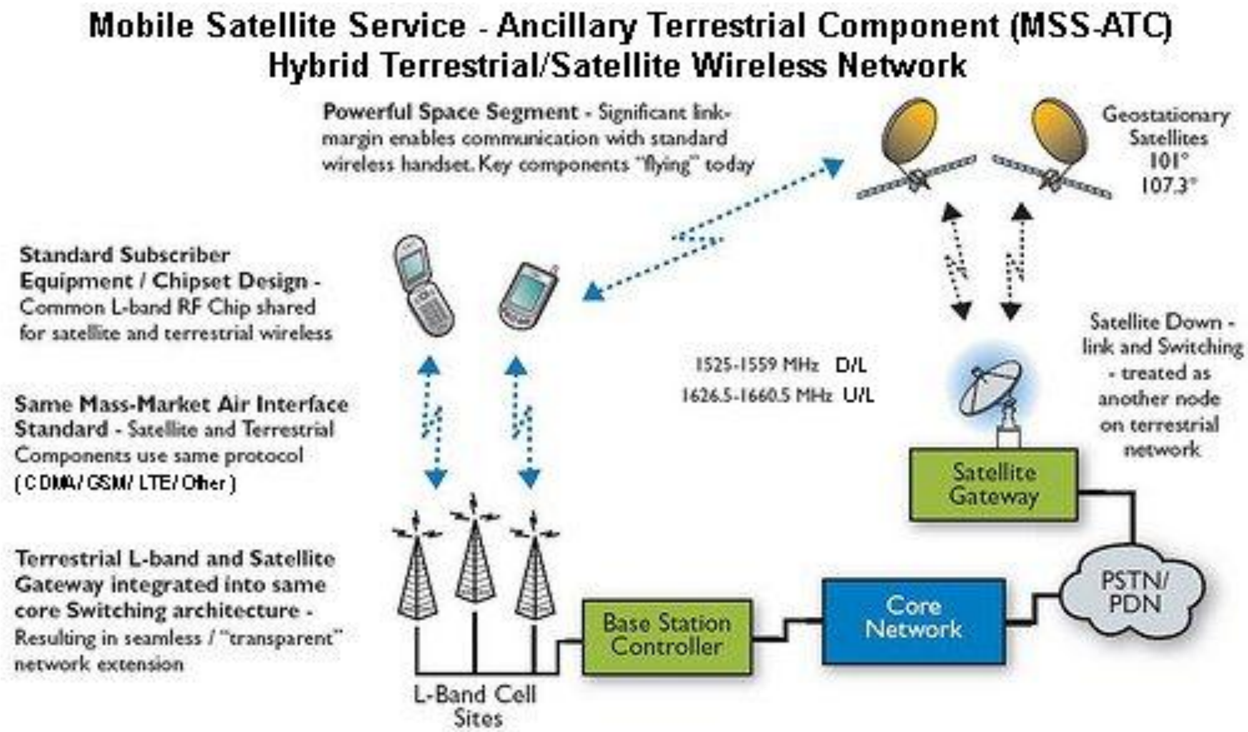
vi. Test equipment should be identical to real world deployments. Because increased interference can result from particular antenna configurations, LightSquared must be required to use the same antenna design as they will eventually deploy. Test results cannot be valid until this takes place.

vii. TWG or FCC should conduct testing to determine how far LightSquared's "stand-off zone" must be from aircraft standing areas and navigable waterways. Because it is not possible to turn up a ubiquitous network with a standard base station configuration given these limits, it will likely be necessary to test additional low-powered/high-density solutions (such as picocells) for their interference potential.

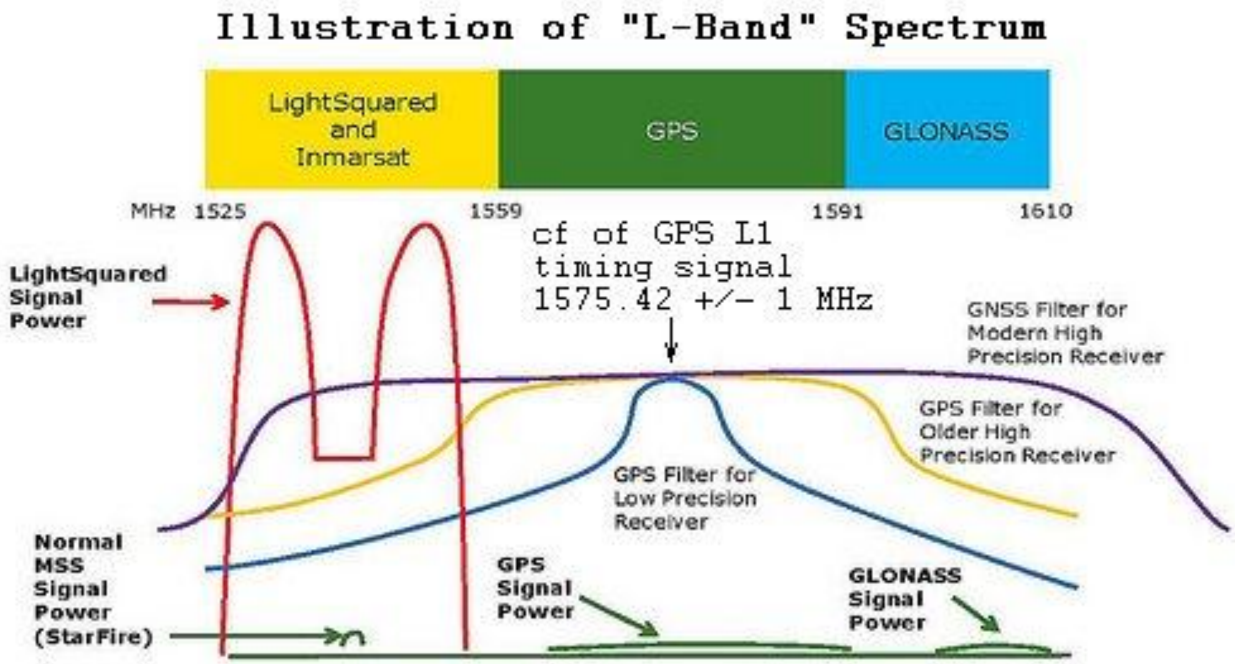
viii. We recommend additional examination of the impact to co-located base station GPS receivers, in both the tower to ground-mount and the rooftop mount configurations, using both lower band only signals (including both of the lower 5 MHz channels) and dual-band signals, if upper band spectrum remains viable.

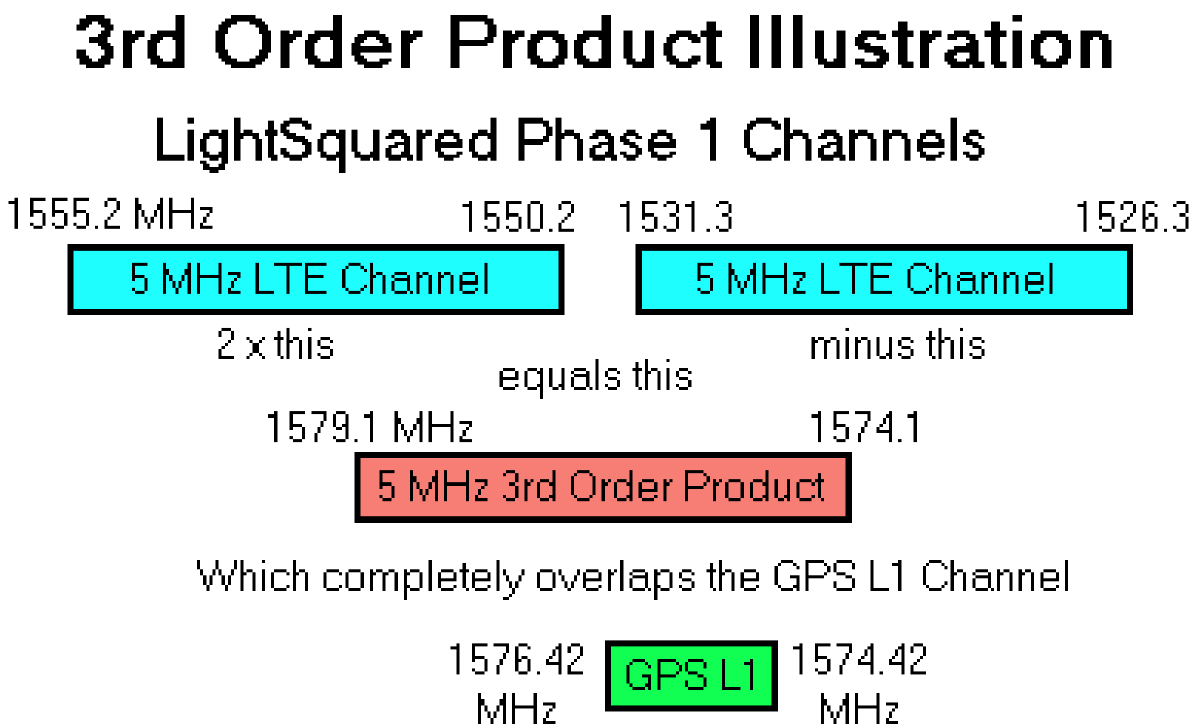
Appendix

LightSquared, Proposed Network Architecture



The GPS "L1" band





This slide demonstrates a possible “3rd Order” Passive Intermodulation product that could be generated from at any dissimilar metal junction on a rooftop or tower and radiate into our GPS receiver, interfering with the weak satellite signal.

LightSquared, Impact of 2° Vertical Downtilt

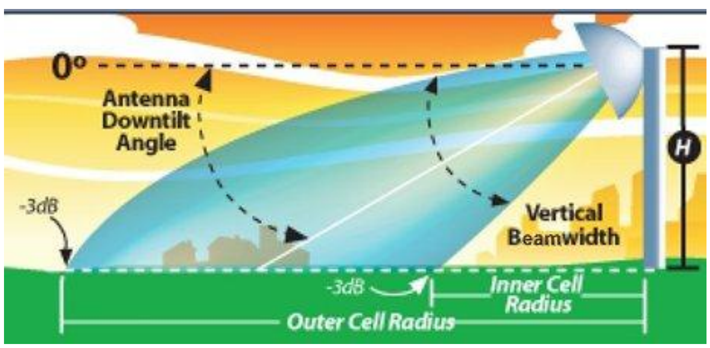
For LightSquared antennas with 7.5 degree vertical beamwidths

LVGS0217 - 235' antenna height, .44 miles inner radius to horizon outer radius

LVGS0160 - 50' antenna height, .09 miles inner radius to horizon outer radius

LVGS0068 - 55' antenna height, .10 miles inner radius to horizon outer radius

LVGS0053 - 60' antenna height, .11 miles inner radius to horizon outer radius



LightSquared – Antenna Specifications

TONGYU COMMUNICATION

TDJ-151717DE-65F

XPol 1525～1710MHz 65° 17dBi Adjustable Electrical Downtilt Antenna, Manual or by optional RCU (Remote Control Unit)

Electrical specifications			
Frequency range (MHz)	1525～1559	1626.5～1660.5	1670～1710
Polarization	±45°		
Gain (dBi)	16.5	17	17
Electrical downtilt (°)	0～10		
Half-power beam width (°)	Hor:65 Vert:7.5		
Sidelobe suppression (dB) (First sidelobe above main beam)	0°...5°...10° 17...17...17		
Front-to-back ratio (dB)	≥ 30 (+/- 20°)		
Isolation (dB)	≥30		
Cross-polar ratio (dB)	≥15(Maindirection 0°)		
Impedance (Ω)	50		
VSWR	≤1.4		
Maximum input power (W)	250W		
Lightning protection	DC Ground		

Clearwire – Nominal GPS Antenna (Symmetricom)

58532A Specifications and Operating Characteristics

Electrical	
Frequency Range (3 dB Bandwidth)	1575.42 MHz ±10 MHz (typical)
Polarization	Right-hand circular
Output Impedance	50Ω (typical)
Total Gain	>30 dBi (38 dBi typical @ elevation angle 90°)
Out-of-Band Signal Attenuation	60 dB (typical) at 1575.42 MHz ±50 MHz
Noise Figure	<2.2 dB (1.8 dB typical)
VSWR	<2.5 (1.5 typical)
dc Power	5 Vdc ±0.5 Vdc, <27 mA (20 mA typical)
Physical	
Connector	Type-N Jack
Dimensions	
Antenna without Mounting Base	90 mm D x 128 mm H (includes connector)
Mounting Base	43 mm I.D. , 75 mm O.D., 65 mm H
Mounting Mast (Option AUB)	38 mm I.D., 42 mm O.D., 355 mm L
Weight	
Antenna without Mounting Base	187 g
Mounting Base	240 g
Mounting Mast (Option AUB)	250 g

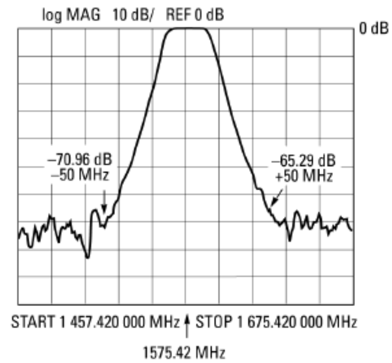


Figure 1. Relative amplitude versus frequency response for 58532A GPS L1 Reference Antenna.

PCTel – Filtered GPS Antenna

GPS-TMG-HR-26N, 26 dB Internal Amplifier With Enhanced Narrow Band Filtering

Antenna Element Electrical Specifications

Frequency Band	Antenna Gain	Nominal Impedance	VSWR	Polarization	Connector
1575.42 +/- 10 MHz	3.5 dBic	50 ohms	≤1.5:1	Right hand circular	N, female (one - bottom fed)

Mechanical Specifications

Antenna Dimensions	Shipping Dimensions	Antenna Weight	Shipping Weight	Radome Color
5.0" H x 3.2" D (126 H x 81 mm)	7.5" L x 4.4" W x 3.8" D (190 L x 112 x 96 mm)	0.6 lbs (0.3 kg)	1.9 lbs (0.9 kg)	White

Environmental Specifications

Temperature Range	Humidity
- 40°C to + 85°C	95%

Mounting

All mounting options fit pipes of 1"-1.45" (25 mm-37 mm) maximum diameter.

Model	Options
GPS-TMG-HR-26N	Does not include mounting hardware.
GPS-TMG-HR-26NMS	Includes universal mounting hardware consisting of collar (GPS-TMG-MNT-R) and pipe clamp (GPS-TMG-LMNT).
GPS-TMG-HR-26NCM	Includes red powder coated collar mount (GPS-TMG-MNT-R)

PCTEL

Low Noise Amplifier Specifications*

Frequency Band (MHz): 1575.42 +/- 1.2 MHz
Amplifier Gain: 26.5 dB +/- 3 dB
Nominal Impedance: 50 ohms
Output VSWR: < 2.0:1
Maximum Noise Figure: ≤ 4.5 dB @ +25°C including pre-selector
Operating DC Voltage: 3.3- 12.0 V (regulated)
Survival DC Voltage: 24V
DC Current: ≤ 40 mA @ 5V
Filtering: 4-stage filtering including pre-selector
Out-of-Band Rejection: ≥ 65 dB @ 1559 MHz ≥ 65 dB @ 1625 MHz
Lightening Protection Compliance: Per EN61000-4-5 Level 4